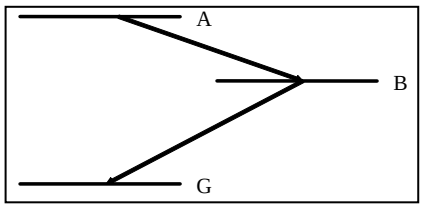
Due: Tuesday, 03/22

17. In hydrogen, the $2^2s_{1/2}$ state lies above the $2^2p_{1/2}$ state by the Lamb shift δ=1058 MHz. In the absence of external electric fields, the $2^2s_{1/2}$ state has very long natural lifetime (≈1/8 sec) and decays by 2-photon emission to the ground $1^2s_{1/2}$ state. The $2^2p_{1/2}$ state has short lifetime ($\tau_{2p} \approx 1.6\cdot10^{-9}$ sec) since it can decay by single E1 photon emission to the ground state (Lyman α line). When an external electric field is applied, the $2^2s_{1/2}$ state acquires an admixture of the $2^2p_{1/2}$ state and its lifetime is shortened.

a) For weak electric fields, show that if the 2s state is populated at time $t=t_0$, its population decays with inverse lifetime $\tau^{-1} = \dfrac{3\gamma \cdot e^2 \cdot a_0^2 \cdot E^2}{\hbar^2\left(\omega_{sp}^2 + \dfrac{\gamma^2}{4}\right)}$. Here $\omega_{sp}=2\pi\delta$, and $\gamma=1/\tau_{2p}$. Explain which electric fields can be considered 'weak'.

b) Evaluate τ at E = 10 V/cm.

18. Consider an atom which has an excited state A of the same parity as the ground state G (see the level diagram) which decays to an opposite parity state B which in turns decays into the ground state. Suppose initially states A and B are not populated. Then at $t=t_0$, state A is instantly populated. Suppose also that in an experiment, one detects fluorescence on the BG transition and the detection system is not sensitive to fluorescence at the wavelength of the AB transition.



a) Derive the time dependence of the fluorescence signal in terms of the lifetimes τ_A, τ_B.

b) Analyze the limiting cases: $\tau_A >> \tau_B$, $\tau_A << \tau_B$, $\tau_A \approx \tau_B$.

c) Will the above analysis modify if the state A has other decay channels apart from AB?

d) The figure shows actual data from an experiment with atomic dysprosium. The state A (E=19797.96 cm^{-1}) was populated with a sequence of two short (≈7 ns) laser pulses. Fluorescence on the BG transition was detected with a fast photomultiplier (the fluorescence peak appears upside down on the figure because the output of the photomultiplier has negative polarity). An interference filter was used to select fluorescence on the BG transition at 564 nm. The data points on the figure were fitted to the expected time dependence (part a); the free parameters of the fit were: t_0, the overall signal amplitude, τ_A, τ_B. Using the figure, estimate τ_A, τ_B.